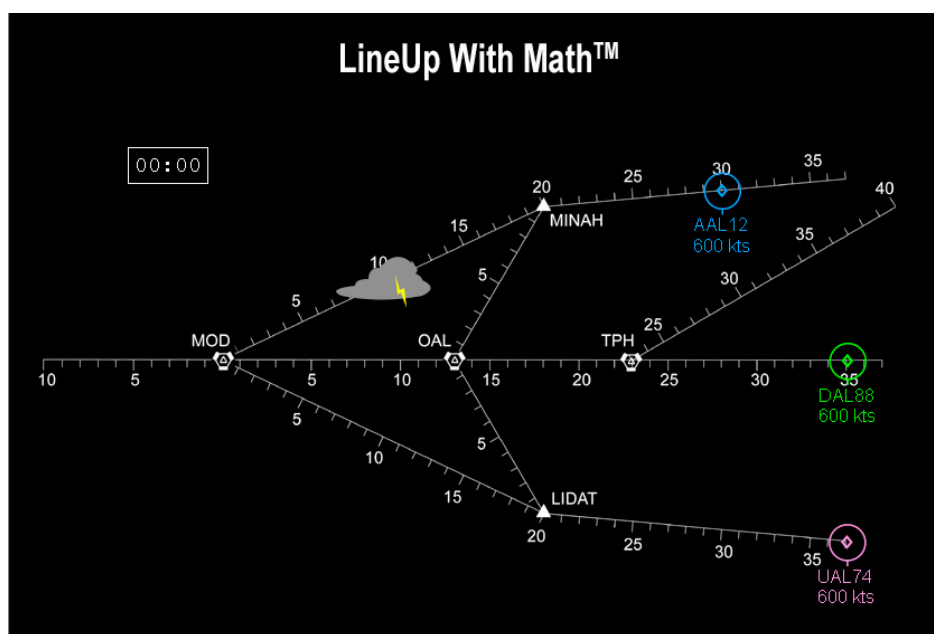National Aeronautics and Space Administration

An Educator Guide to

LineUp With Math™

Math-Based Decisions in Air Traffic Control
Grades 5-9

Interactive Simulator

Workbook

Educational Product	
Educators & Students	Grades 5-9

A *Smart Skies*™ Product

ACKNOWLEDGMENTS

All materials are free and available to download from the *LineUp With Math™* websites:

Teacher website: **http:/www.smartskies.nasa.gov/lineup**

Student (Simulator): **http://www.atcsim.nasa.gov**

LineUp With Math™ is also available in electronic format through the NASA Education Portal—NASA's electronic resources specifically developed for the educational community.

http://www.nasa.gov/audience/foreducators/topnav/materials/about/index.html

Table of Contents

Educator Guide for *LINEUP WITH MATH*[TM]

BECOMING ACQUAINTED WITH
LINEUP WITH MATH[TM]

A *Smart Skies*[TM] Educational Product

What is *LineUp With Math*[TM]?	*LineUp With Math*[TM] enables students to explore and apply decision-making and proportional reasoning skills to resolve distance-rate-time problems in realistic air traffic control situations. To solve the problems, students use a web-based interactive Air Traffic Control (ATC) Simulator that represents an air traffic controller's screen. The accompanying Workbooks provide the underlying mathematics and strategies to enable students to optimize their solutions.

LineUp With Math[TM] consists of six Problem Sets. Each typically contains:
- interactive ATC Simulator problems (web-based)
- a Student Workbook (print-based)
- supporting teacher materials

Access to Materials

All *LineUp With Math*[TM] materials, including the interactive ATC Simulator, are free and accessible from the *LineUp With Math*[TM] teacher website: (See Appendix I for a brief introduction to the website.)

> http://www.smartskies.nasa.gov/lineup

Student access to the ATC Simulator is available at the following address:

> http://www.atcsim.nasa.gov

Quick Start Guide

For a brief introduction to the *LineUp With Math*[TM] materials and ways to use these materials in your classroom, see the *LineUp With Math*[TM] Quick Start Guide available on the teacher website.

Background

LineUp With Math[TM] was developed under *Smart Skies*[TM], a key part of the NASA Airspace Systems Program's educational efforts. The Program's goal is to develop advanced computer-based systems to help pilots and air traffic controllers operate the nation's air transportation system with reduced flight delays and improved efficiency and access.

In the first *Smart Skies*[TM] product, *FlyBy Math*[TM], students conduct experiments and use a variety of math methods to analyze traditional distance-rate-time problems in air traffic control. As students identify conflicts in these 2-plane problems, they develop and apply proportional reasoning to predict distance-rate-time relationships.

Standards

State Standards Alignment: For each of the 50 states, the alignment of *LineUp With Math*[TM] with the state mathematics standards is available on the *LineUp With Math*[TM] website.

National Standards Alignment: The alignments of *LineUp With Math*[TM] with the National Council of Teachers of Mathematics (NCTM) Standards and Expectations and the National Science Education Standards (NSES) are available on the *LineUp With Math*[TM] website.

Overview

In *LineUp With Math*[TM]*,* the second *Smart Skies*[TM] product, students apply proportional reasoning to make decisions and resolve conflicts in realistic air traffic control problems involving two or more planes. The challenge in each problem is to "line up" the planes safely, with proper spacing, at a given intersection of jet routes.

Before   **After**

Students typically explore the problems using an interactive Air Traffic Control (ATC) Simulator. To increase and refine their decision-making skills, students use the print-based Student Workbooks that provide instruction and practice in mathematics and strategies to enable them to optimize their solutions. After completing the Student Workbooks, students return to the Simulator and apply their newly learned skills to properly line up the planes while also optimizing the time for the last plane to reach the final intersection.

LineUp with Math[TM] addresses the following types of ATC problems:

- two-plane and three-plane conflicts resolved with route changes
- two-plane and three-plane conflicts resolved with speed changes
- three-plane, four-plane, and five-plane conflicts resolved with speed changes or with speed and route changes.

LineUp with Math[TM] uses an airspace based upon a real sector in the National Airspace System. The sector, formally designated as ZOA33 and referred to as Sector 33, is located in northern California. In *LineUp with Math*[TM], the sector distances have been modified to simplify student calculations.

6 Problem Sets

The *LineUp With Math*[TM] instructional materials have been packaged in the form of six Problem Sets.

- Problem Set A: An introduction to the environment of real air traffic control.
- Problem Sets B and C: Analysis of conflicts between two or three planes and resolution of the conflicts by rerouting.
- Problem Set D: An introduction to the basic effects of differences in speed.
- Problem Sets E and F: Analysis of conflicts between two or three planes and resolution of the conflicts by changing plane speed.

Each Problem Set contains:

- an interactive or multimedia component (e.g., Simulator, movies)
- a Student Workbook
- a Teacher Guide with answers to the Workbook and to the featured Simulator problems

Each of these components is described below.

ATC Simulator

The interactive ATC Simulator is a web-based computer program that teachers can access from the *LineUp With Math*^{TM} website or directly from a separate simulator website that gives students easy access to the ATC Simulator **only** (and not to the answers and solutions provided on the teacher website):

<div align="center">http://www.atcsim.nasa.gov</div>

The Simulator provides a user-friendly realistic simulation of Sector 33 as viewed by a controller on a sector display screen. At the beginning of each Simulator problem, two or more planes travel along merging jet routes. Students, preferably working in pairs or individually, use proportional reasoning and distance-rate-time relationships to identify potential conflicts at the intersections of the jet routes. Depending upon the problem, students can resolve the conflict by changing plane routes or plane speeds.

As mentioned previously, the goal is to "line up" the planes safely, with proper spacing, at a given intersection. Students can rerun a problem to refine their solution and bring each plane to the intersection, not only safely, but also as quickly as possible. (The target time shown on the simulator screen for each problem is the optimal time for that problem.)

The Simulator features problems with 2, 3, 4, and 5 planes. The key two- and three-plane problems are supported by the Student Workbooks. The remaining two- and three-plane problems provide additional practice. The four- and five-plane problems enable students to explore more challenging scenarios.

Each Simulator problem is named with two numbers separated by a hyphen, e.g. 2-5. The first number, 2, corresponds to the number of planes in the problem. The second number, 5, indicates the problem is the fifth in the sequence of 2-plane problems.

The simulator website also includes the following user support materials:

- Animated tutorial
- 2-page quick reference guide
- technical requirements

Background and Instructional Movies

LineUp With Math^{TM} includes three movies available for download on the *LineUp With Math*^{TM} teacher website and on the student Simulator website.

The first video, *"Animation of 24 hours of flight in the U.S."*, compresses 24-hours of US flight paths to 1 minute. The video illustrates the world's biggest distance-rate-time problem and motivates the study of air traffic control.

The second movie, *"What is LineUp With Math*^{TM}?"*, introduces students to the overall goals and activities, and features scenes of students engaged in *LineUp With Math*^{TM}.

The third movie, *"Welcome to Sector 33"*, presents the vocabulary, units, and graphical representations used in air traffic control. It prepares students for their first session with the interactive ATC Simulator. It also prepares students for the activities in the first Student Workbook (Problem Set A).

Student Workbooks

For each Problem Set, a print-based Student Workbook provides a structured learning environment. Each Workbook contains paper-and-pencil worksheets that introduce students to pertinent air traffic control concepts as well as problem analysis and solution methods.

- Problem Set A: Workbook A introduces students to the environment of real air traffic control.
- Problem Sets B and C: Students use Workbooks B and C to analyze conflicts between two or three planes and to resolve the conflicts by rerouting.
- Problem Set D: Workbook addresses the basic effects of differences in speed.
- Problem Sets E and F: Students use Workbooks E and F to analyze conflicts between two or three planes and to resolve the conflicts by changing plane speed.

Workbooks B, C, E, and F include worksheets that support selected Simulator problems. For these worksheets, the title matches the number of the associated Simulator problem.

Four- and five-plane problems are found on the Simulator only and are not supported by the Student Workbooks. These higher-level Simulator problems enable students to explore more challenging scenarios.

Teacher Guides

Each of the six Problem Sets is accompanied by a Teacher Guide that includes:

- an overview
- a list of objectives, prerequisites, and materials
- a discussion and specification of the relevant ATC Simulator Problems (or other interactive/multimedia components)
- a discussion of key points for each Simulator problem and for each Workbook worksheet
- the solutions for each Simulator problem
- the answers for each Workbook worksheet

Instructional Goals

LineUp With Math[TM] has two overarching goals:

- To enable students to use mathematical reasoning and problem-solving skills to investigate and solve realistic distance-rate-time problems in air traffic control.

- To offer students a variety of problem solving approaches, tools, skills, and experiences in the context of challenging, yet accessible, real-world problems.

The following table lists the materials and specific learning objectives for each *LineUp With Math*[TM] Problem Set.

The LineUp With Math™ Problem Sets

Problem Set	Materials	Objectives
A Introduction to air traffic control sectors	☐ *Two Movies* *-- Animation of 24 hours of flight in the U.S.* *-- What is LineUp With Math?* *--Welcome to Sector 33* ☐ *Student Workbook A* ☐ *Teacher Guide A*	• Learn the vocabulary of air traffic control. • Learn the units (nautical miles and knots) of air traffic control. • Learn to read and interpret an airspace sector diagram. • Learn the air traffic control spacing requirements for safety and efficiency.
B 2-plane conflicts: change routes	☐ *Animated Tutorial -- Introduction to the ATC Simulator* ☐ *Simulator Problems 2-1*, 2-2*, 2-3*, 2-9, 2-10* ☐ *Student Workbook B* ☐ *Teacher Guide B*	• Analyze a sector diagram to identify a spacing conflict between two planes, each traveling at the same speed. • Resolve the conflict by changing the route for one plane.
C 3-plane conflicts: change routes	☐ *Simulator Problems 3-1*, 3-2*, 3-7* ☐ *Student Workbook C* ☐ *Teacher Guide C*	• Analyze a sector diagram to identify a spacing conflict among three planes, each traveling at the same speed. • Resolve the conflict by changing the route for one or more planes.
D Effects of speed differences	☐ *Student Workbook D* ☐ *Teacher Guide D*	• Learn that when a plane's speed is reduced, the difference in the plane's distance traveled can be calculated by multiplying the difference in speed by the amount of time traveled. • Learn how to associate a decrease in plane speed in knots with a decrease in distance traveled each minute. • Learn the correspondence between a 60-knot reduction in plane speed and the resulting decrease in distance traveled (in 1 minute) over a 10 Nmi interval on a jet route. (Students will encounter these particular speed reductions and multiples of 10 Nmiles in subsequent Workbooks.)
E 2-plane conflicts: change speeds	☐ *Simulator Problems 2-4*, 2-5*, 2-6*, 2-7*, 2-8*, 2-11, 2-12, 2-13, 2-14, 2-15, 2-16* ☐ *Student Workbook E* ☐ *Teacher Guide E*	• Analyze a sector diagram to identify spacing conflicts between two planes, each traveling at the same speed. • Resolve the conflicts by changing the speed of one plane. • (Optional) Learn that a given percent reduction in plane speed yields the same percent reduction in distance traveled in the original amount of time.
F 3-plane conflicts: change speeds	☐ *Simulator Problems 3-3*, 3-4*, 3-5*, 3-6*, 3-8, 3-9, 3-10, 3-11, 3-12* ☐ *Student Workbook F* ☐ *Teacher Guide F*	• Analyze a sector diagram to identify spacing conflicts among three planes, each traveling at the same speed. • Resolve conflicts by changing the speed of one or more planes. • Resolve conflicts by changing the speed or the speed and route of one or more planes.
* The Simulator problems marked with an asterisk (*) are supported by worksheets in the print-based Student Workbooks.		

PREPARING TO TEACH *LineUp With Math*™

Select Materials

To prepare to teach *LineUp with Math*™:

1. Go to the *LineUp With Math*™ teacher website:

    http://www.smartskies.nasa.gov/lineup

2. On the website, view the movie *"Animation of 24 hours of flight in the U.S."* to see the world's largest distance-rate-time problem.

3. On the website, view the movie "What is *LineUp With Math*™?".

4. On the website, view the movie "Welcome to Sector 33" to see an overview of the vocabulary, units, and graphical representations of air traffic control problems. This material is the backbone of both the simulator and the print-based workbooks.

5. On the website, view the movie "Introduction to the ATC Simulator."

6. Access and try the on-line Simulator. Online instructions are provided to assure that your computer is configured to support the Simulator.

7. Select the Problem Set you will use to introduce your students to *LineUp With Math*™. We strongly recommend starting with Problem Set A.

If you do not want to print the documents, you can simply preview them online.

8. Follow the online instructions to select and download the materials for the Problem Set you have selected.

Review Materials

9. With the student and teacher materials in hand, and with access to the ATC Simulator, read the following Implementation section in this document.

10. Duplicate the Student Workbook to provide each student with one copy.

11. Now you're cleared for takeoff!

IMPLEMENTING *LINEUP WITH MATH*™
WITH YOUR STUDENTS

Instructional Activities	The following sequence of instructional activities is recommended for implementing each *LineUp with Math*™ Problem Set. As you read this section, you may find it helpful to have a copy of a Student Workbook and the associated teacher materials.
.	

Estimated time: 30 minutes	1. If your students are new to *LineUp With Math*™, begin with the three introductory movies:
	    -- *"An animation of 24 hours of flight in the U.S."*
	    -- *"What is LineUp With Math*™*?"*
	    -- *"Welcome to Sector 33."*
	
	The movie clips are available on the *LineUp With Math*™ teacher website.

Estimated time: 30 minutes	2. If your students are new to *LineUp With Math*™, introduce the ATC Simulator. You may want students to view the animated *"ATC Simulator User Tutorial."* You may choose to project the Simulator (and animated tutorial) for a whole class activity. Or you may choose to have the students work on individual computers, in pairs or individually. Students should access the Simulator and movies at the following address: http://www.atcsim.nasa.gov
Estimated time: 30 minutes	3. For the Problem Set you have selected, assign the Simulator problems featured in the Student Workbook. Provide time for your students to explore the Simulator and the assigned interactive ATC problems.
Estimated time: 30 minutes	4. For the Problem Set you have selected, assign the worksheets in the accompanying Student Workbook.
Estimated time: 30 minutes	5. After students have completed the Workbook, have them revisit the assigned problems on the Simulator to see if they can optimize their solution and match the target time on the Simulator screen. You may also wish to assign some of the supplementary Simulator problems. (See the table in the Instructional Goals section of this document or consult the Teacher Guide for the Problem Set.) If you plan to teach a subsequent Problem Set, you may want to have your students experiment with the first few Simulator problems from that Set.
Materials	**Classroom Materials:** -- Movie clips -- ATC Simulator -- Student Workbook for selected Problem Set -- Simulator Quick Start Guide

Teacher Materials:

-- Teacher Quick Start Guide
-- *LineUp With Math^{TM}* Educator Guide (this document)
-- Teacher Guide for selected Problem Set with answers to all worksheets and solutions to featured Simulator problems
-- Complete set of solutions to all ATC Simulator problems

NASA RESOURCES FOR EDUCATORS

NASA has a rich supply of resources for educators and delivery methods ranging from print-based, multimedia, and television.

These resources can all be accessed from the NASA web portal at:

http://www.nasa.gov

Select the "for EDUCATORS" button to access the educational materials.

They may also be accessed from the *Smart Skies^{TM}* website at:

http://www.smartskies.nasa.gov

Select the RESOURCES button.

PROVIDING NASA WITH YOUR ASSESSMENT

In order to ensure that these educational materials are the best they can be for teachers and students across the nation, NASA needs your feedback and suggestions.

Please take a few minutes to fill out the *Educator Reply Card* located under the CONTACT US button on the *Smart Skies^{TM}* website:

http://www.smartskies.nasa.gov

Thank you!

APPENDICES

Appendix I - LineUp With Math™ Website Home Page

All Student Materials

NCTM and State Standards Alignments

LineUp With Math™

Smart Skies™

+ TEACHER MATERIALS | + STUDENT MATERIALS | + STANDARDS | +SIMULATOR | + VIDEOS | + CONTACT US

All Teacher Materials

Math-Based Decisions in Air Traffic Control (ATC) Grades 5 - 9

Join the Smart Skies™ teacher discussion group!

$$D = R \cdot T$$

LEARN ABOUT LINEUP WITH MATH™

Product Overview

First time? Start here!

What's *LineUp With Math*™ ?

Read an Overview
View a Video
Read the Educator Guide (520 KB PDF)

Can you line up the planes?

An interactive Air Traffic Simulator...

Read About the Simulator

Can you do the math?

...and 6 problem sets.

Explore the Problem Sets

CLICK BELOW TO ACCESS THE SIMULATOR AND 6 PROBLEM SETS

Everything you need for a Problem Set

1 ATC INTRO

2 CHANGE ROUTE

3 CHANGE ROUTE

Sector 33

4 SPEED INTRO

5 CHANGE SPEED

6 CHANGE SPEED

Access to Simulator and Student Website

Appendix II - Glossary

Aircraft	Device(s) that are used or intended to be used for flight in the air, and when used in air traffic control terminology, may include the flight crew.
Air Traffic	Aircraft operating in the air or on an airport surface, exclusive of loading ramps and parking areas.
Airspace	The space lying above the earth or above a certain area of land or water, especially the space lying above a nation and coming under its jurisdiction.
Air Traffic Control	A service operated by appropriate authority to promote the safe, orderly and expeditious flow of air traffic.
Call Sign	The unique designator for each flight. Is composed of a 3-letter abbreviation for the airline name and a unique flight number.
Conflict	When 2 aircraft do not meet the minimum separation standards.
Flight Plan	Specified information relating to the intended flight of an aircraft that is filed orally or in writing with an FSS or an ATC facility.
Flight Path	A line, course, or track along which an aircraft is flying or intended to be flown.
Ideal Spacing	In air traffic control, the distance between aircraft to assure their orderly movement.
Knot	Units of speed for air and sea travel. One knot equals one nautical mile per hour.
Minimum Separation	In air traffic control, the minimum allowed distance between aircraft to achieve their safe movement in flight and while landing and taking off.
Nautical Miles	Unit of measure for distance in air and sea travel. A nautical mile is 1.15 times a statute mile used in land travel.
Route	A defined path, consisting of one or more courses in a horizontal plane, which aircraft traverse over the surface of the earth.
Sector	A geographic area of the airspace for which a controller is responsible.